Assessing Permittivity Frequency Response in GelMA/NaCl Hydrogels for Dielectrically Accurate Tissue Phantoms

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Statement of Purpose: Tissue phantoms are constructs that can accurately mimic the mechanical, electrical, and chemical properties of tissues. Electrically accurate tissue models that can measure bioimpedance measurements are especially vital for the development of medical devices. However, the electrical response within tissues is not constant across all frequencies, which makes material selection to develop accurate tissue phantoms a significant challenge. Previous research has demonstrated the feasibility of utilizing a combination of gelatin and NaCl to create dielectrically accurate tissue phantoms.[1] In this work, we first generated dielectric frequency plots of various dermal tissues with literature values and compared their response to that of gelatin/NaCl hydrogels.[2] We then attempted to evaluate the feasibility of utilizing GelMA and NaCl to mimic the dielectric response of dermal tissue and ultimately created an apparatus test the frequency response within GelMA/NaCl hydrogels.

Materials and Methods: The frequency response of the dielectric constant of relevant dermal tissues (Dry Skin, Subcutaneous Fat, Tendon) were obtained by plotting literature dispersion parameters[1] using modified Cole-Cole dielectric dispersion equations and compared to that of gelatin/NaCl casts utilized in previous studies.[1] A curve fitting algorithm that extracts the modified Cole-Cole dispersion parameters from permittivity-frequency plots was developed. The efficiency of the algorithm was tested by performing a curve fit on the permittivity plots and computing the error. Then, a parallel plate capacitor setup with GelMA/NaCl disks acting as the dielectric was assembled to evaluate the dielectric frequency response of various GelMA/NaCl formulations (Figure 1A). Aluminum 6061 electrode plates (40 mm diameter, 1 mm height) were fit into the apparatus to form a parallel plate capacitor when unified with the casted GelMA/NaCl hydrogel discs. The resulting GelMA/NaCl capacitors were measured for electrode surface area overlap and height.

Results and Discussion: Permittivity frequency dependence of actual dermally relevant tissue resembles the frequency responses of gelatin/NaCl casts of previous studies (Figure 1B).[1] The computational results confirmed that gelatin-based materials supplemented with NaCl can be used to create dielectrically accurate tissue phantoms by modifying the NaCl concentration. Interestingly, dry skin possessed a different frequency dependence than that of gelatin/NaCl hydrogel. Hydrated portions of the skin, such as the dermis and hypodermis layers, may have more congruous relationships to the gelatin/NaCL casts. Additionally, the fabrication of the parallel plate apparatus to the prescribed dimensions was successful and will be used for future experimental measurements.

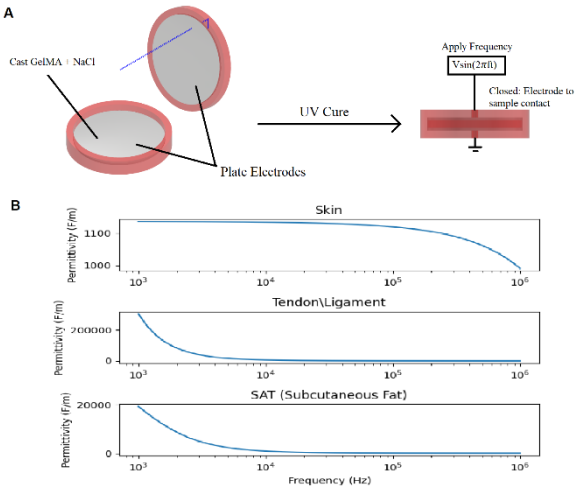

Figure 1. (**A**) Casting/Measurement apparatus and UV curing process. (**B**) Permittivity dependence on frequency in dermal relevant tissues.

Conclusions: This project aimed to develop a dielectrically accurate tissue phantom utilizing GelMA and ionic salts for *ex vivo* bioimpedance measurements. Future work will be directed in evaluating the dependence of GelMA and NaCl concentration on the Cole-Cole dispersion parameters for fitting the responses of other tissue types using the described parallel plate apparatus.

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References:

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2. Gabriel S., et al. *Physics in Medicine and Biology*. 1996; *41*(11), 2271–2293